Variations of scaling relationships for shallow tremor; implications from the probabilistic cell automaton model

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Scaling relationships of seismic phenomena is one of keys to understand the source processes. In our previous study, the event size distribution of shallow tremor that occurred along the Nankai trough was well fitted by the tapered Gutenberg-Richter (TGR) (Kagan 2002 GJI) distribution (Nakano et al. 2019 GRL). In that study, the cutoff magnitude (Mc) of TGR, above which the event size distribution is well fitted by an exponential law, and the b-value (slope of the size distribution in logarithmic scales smaller than Mc) varied in each activity period. Detailed analysis showed that both Mc and the b-value temporally changed DURING activities in 2016 off Kumano and 2018 off Muroto (Nakano et al. 2019 JpGU). To clarify the factors that control the event size distribution may help our understandings of slow earthquake source mechanisms. In this study, we try to explain the observed changes in the event size distribution based on the 2D probabilistic cell automaton (PCA) model proposed by Ide and Yabe (2018 PAG), which well explains the statistical properties of the broadband slow earthquakes including event size distributions.

In the 2D PCA model, each cell has two states: “stop” and “slip”, which probabilistically alternates according to the states of neighboring cells. The controlling parameters of the 2D PCA model would be: the source size in x and y directions (Nx and Ny), the transition probability of the cell status (pb), ignition of fault slip (pl), and energy dissipation during slip (pv).

Our simulations show that the source size (Nx and Ny) and pb changes Mc without significantly affecting the b-value as already shown by Ide and Yabe (2018) (their Figure 4). On the other hand, increasing the excess stopping probability (pv) due to energy dissipation systematically reduces Mc while increases the b-value, namely smaller-size events predominate due to the suppression of event growth. The effects of ignition (pl), or loading, is small compared to pv, but further detailed studies are necessary because these parameters would affect the system in a similar way.

The observed changes in Mc and the b-value in the shallow tremor showed negative correlations in these parameters. In the 2016 off Kumano activity, Mc decreased in the end 5 days of the activity synchronized with the b-value increase and event number decrease. In the 2018 off Muroto activity, decreases in Mc was observed in the middle 30 days and end 30 days during 4 months activity, synchronized with the b-value increases and event number decreases. The observed changes in the size distributions can be explained by increase in the excess stopping probability (pv) during the lower activity periods.

In this study, we showed that the changes in pv systematically explains the observed temporal changes in the event size distributions of the shallow tremor, but its physical meaning is not clarified yet. Temporal changes in the stopping probability of cell movement in PCA may correspond to changes in the frictional properties along the causative fault. Further careful investigations based on experimental and/or theoretical studies to clarify materials that control the frictional properties on a fault, which changes could occur in a several to ten days, is necessary.

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